

Species Report for the Band-rumped storm-petrel (*Oceanodroma castro*)
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Band-rumped storm-petrel Species Report, Final Draft

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EXECUTIVE SUMMARY

The band-rumped storm-petrel (*Oceanodroma castro*; ‘akē‘akē) is a small seabird measuring approximately eight inches long with a wingspan of 19 inches (in) (47 centimeters [cm]) and weighing about 2 ounces (oz) (50 grams [g]). The Hawai‘i Distinct Population Segment (DPS) nests in the Hawaiian archipelago, and ranges throughout the Pacific Ocean basin while foraging. There is one single population that breeds within the Hawaiian Islands. In Hawai‘i, band-rumped storm-petrel breeding is confirmed or likely on Lehua, Kaua‘i, Lāna‘i, and Hawai‘i. They may also breed on Maui, but no nesting sites have been confirmed. Due to its cryptic nature and remote nesting habitat, only four active nests have been confirmed in Hawai‘i, all on the northern slope of Mauna Loa. Breeding is suspected in other areas as indicated by ground calling and the presence of brood patches in captured birds. There are a total of nine breeding sites, five of which are extant.

There are a number of threats that band-rumped storm-petrels face including climate change, invasive species and habitat modifications, predation, stochastic events, light attraction and fallout, collisions, wind farms, fisheries interactions, and inadequate regulatory mechanisms. Conservation actions for band-rumped storm-petrels include the establishment of ungulate exclusion areas, the implementation of social attraction at predator-proof fence sites, the active capture and removal of mammalian and avian invasive predators, effective outreach urging residents to limit nighttime lighting during seabird fledgeling season, installation of light shields, addition of diverters to power lines, as well as the establishment of a rehabilitation program that reintroduces seabirds back to the wild.

The species viability is measured by assessing the conservation principles of resiliency, redundancy, and representation. In this report, we identify resiliency as the capacity of a species to survive stochastic events and ecological disruption and use population size as our measurement of that ability. Redundancy is defined by the number of breeding sites across the species range and their distribution and connectivity. For redundancy, we will use the number of distinct populations over the habitat range, as well as the connectivity throughout Hawai‘i. Finally, representation is defined as maintaining genetic diversity by having environmental variation in nest sites as well as population structure, thereby increasing the ability to survive changing environmental conditions over time. We define representation by the number of nesting sites in each habitat type, as well as the genetic population structure.

Because there are a limited number of populations, the total population size is unknown, the level of threats is very high, and protected nesting habitat is limited, we have assessed the overall viability of band-rumped storm-petrels as low.

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INTRODUCTION

The Hawai‘i Distinct Population Segment (DPS) of the band-rumped storm-petrel (*Oceanodroma castro*, ‘akē‘akē), is an endangered seabird that is found throughout the Pacific Ocean basin, and nests in the Hawaiian Islands. This species is known to nest in near vertical cliff habitats, as well as barren lava fields.

Species Report Overview

This Species Report summarizes the biology and current status of the band-rumped storm-petrel and was conducted by Pacific Islands Fish and Wildlife Office. It is a biological report that provides an in-depth review of the species’ biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the Service’s Endangered Species Program. As such, the Species Report will be a living document and biological foundation for other documents such as recovery plans, status in biological opinions, and 5-year reviews.

Regulatory History

The Hawai‘i DPS band-rumped storm-petrel was listed as endangered under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), as amended (ESA) on October 31, 2016 (USFWS 2016). Critical habitat has not been designated for this species. In the 2015 listing package, the Hawai‘i DPS was determined based on: 1) the population segment’s discreteness from the Japan and Galapagos populations, and 2) the fact that the loss of the Hawai‘i population would result in a significant gap in the range of band-rumped storm-petrels (USFWS 2015). In November of 2019, a proposed rule was published to revise the name *Oceanodroma castro* to *Hydrobates castro* on the list of migratory bird species as a result of recent taxonomic revisions (USFWS 2019a). However, the current listed entity remains *Oceanodroma castro*.

Methodology

We used the best scientific and commercial data available to us, including peer-reviewed literature, grey literature (government and academic reports), and expert elicitation.

Because little information is available about the band-rumped storm-petrel, we used data available for a congener or otherwise similar species of the same genus or family to fill in data gaps such as basic avian biology to identify needs of individuals, populations, and species.

To assess the current status and viability of band-rumped storm-petrels we identified population units, for which only a single population exists in the Hawai‘i DPS. The classic definition of a population is a self-reproducing group of conspecific individuals that occupies a defined area over a span of evolutionary time, an assemblage of genes (the gene pool) of its own and has its own ecological niche. However, due to information gaps, we could not assess the viability of band-rumped storm-petrels using this definition. We have no further data with which to delineate more refined populations, though it is possible that separate colonies may act like population units if additional information was collected. In this report, we examine breeding locations among the islands, identifying both active and historical locations.

Based on this working definition, maps were created to display breeding areas. Maps were based on islands where current breeding sites are known or suspected. Given that very few burrows have been discovered, generalized locations based on evidence of ground-calling, mist-net captures, and other physical evidence were used to assess the Hawai'i DPS population. In an effort to protect the sensitivity of species data, we created maps with shaded generalized breeding ranges rather than displaying species points or polygons. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

Species Viability

The Species Report assesses the ability of band-rumped storm-petrels to maintain viability over time. Viability is the ability or likelihood of the species to maintain its population over time, i.e., likelihood of avoiding extinction. To assess the viability of band-rumped storm-petrels, we used the three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs” (Figure 1; USFWS 2016a, entire). We will evaluate the viability of a species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

Definitions

Resiliency is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may also influence the connectivity among populations.

Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

Representation is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resilient populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for the band-rumped storm-petrel.

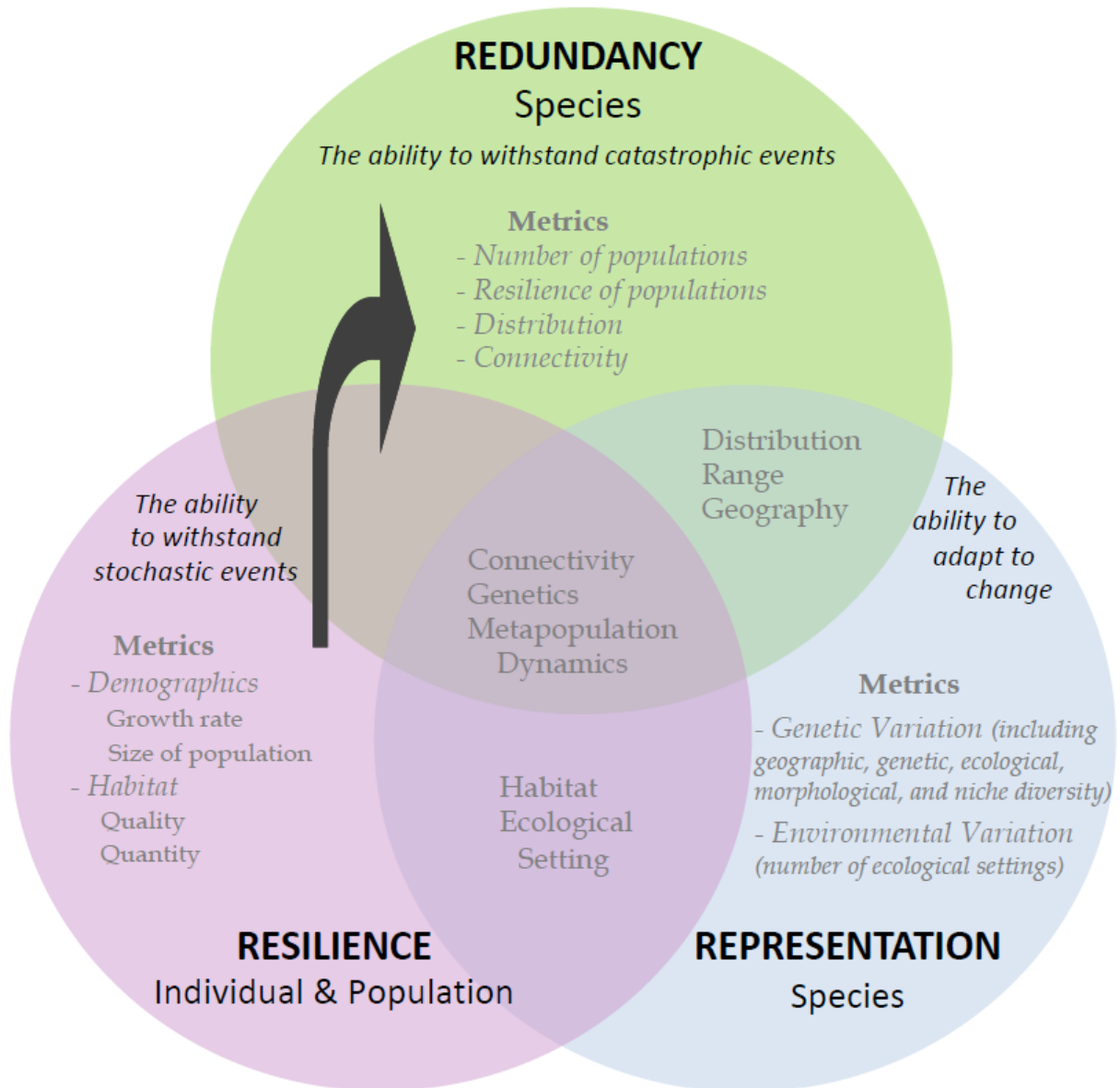


Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the “3Rs”.

SPECIES ECOLOGY

Species Description

Band-rumped storm-petrels are a small seabird measuring approximately 8 in (20 cm) long with a wingspan of 19 in (47 cm), and weighing about 2 oz (50 grams). The tail is only slightly notched and is almost square in appearance. Plumage is an overall blackish-brown with a white band across the “rump,” just above the tail. This species typically flies with a relatively shallow wing-beat and glides on slightly bowed wings as a regular part of flight (Slotterback 2002a, p. 2). Both sexes are alike in size and appearance. Vocalizations at breeding colonies can be used to

further distinguish this species from other Procellariiformes seabirds found throughout Hawai‘i (Allan 1962, p. 279; James and Robertson 1985, pp. 391–392).

Band-rumped storm-petrels are found in several areas of the subtropical Pacific and Atlantic oceans (Slotterback 2002, p. 1). The genus name *Oceanodroma* comes from the Greek words for “ocean runner” (the proposed genus *Hydrobates*, also Greek, for “water walker”), which describes how the bird appears to walk or run on the ocean surface while feeding at sea. The genus *Oceanodroma* is paraphyletic to *Hydrobates*, which has priority, and thus the current taxonomic classification for this species is *Hydrobates castro* (USFWS 2019a, p. 60999). The ESA listing remains under *Oceanodroma castro*, which is used here for consistency. In the Pacific, there are three widely separated breeding populations – one in Japan, one in Hawai‘i, and one in the Galapagos Islands (Slotterback 2002, p. 1). The Hawaiian population of Band-rumped storm-petrels was previously considered a subspecies, *Oceanodroma castro cryptoleucura*, but recent assessments determined that geographic distances alone were not sufficient to warrant subspecies designation (Harris 1969, p. 97; Wood et al. 2003, p. 1). The Hawai‘i DPS of band-rumped storm-petrels is found throughout the main Hawaiian islands, and forages in the Pacific Ocean basin. Designation of the Hawai‘i DPS for band-rumped storm-petrels was warranted because the loss of the Hawai‘i population would result in a significant gap in the range of the taxon, and this population persists in a unique ecological setting (USFWS 2016, p. 67820). In the literature, band-rumped storm-petrels are also referred to as Harcourt’s storm-petrel, and occasionally the Madeiran storm-petrel, with the latter referring to populations that are found in the Atlantic.

In Hawai‘i, band-rumped storm-petrel breeding habitat is primarily wet cliff and dry cliff ecosystems. Band-rumped storm-petrels likely nest in remote cliff locations on Kaua‘i, Lehua, and Lāna‘i, and in high-elevation lava fields on the island of Hawai‘i (Wood et al. 2003, pp. 6, 8, 11, 13, 17; VanderWerf et al. 2007, p. 42; Galase 2019, p. 27). Band-rumped storm-petrel calls have also been detected near cinder cones on the southeast slope of Mauna Loa above 6,562 feet (ft; 2,000 meters [m]) and on the slopes of Haleakalā on Maui, indicating potential breeding in these areas (Banko et al. 2001, p. 653; Raine et al. 2020a, p. 94). Due to the remote and often vertical nature of their nesting habitat, the only active nest that has been confirmed is in the Pōhakuloa area of the island of Hawai‘i, on the slopes of Mauna Loa (Galase 2018). Three other inactive nests have been found in the Hawaiian Islands, one in a small lava tube at 8,500 ft (2,591 m) elevation on the southeastern slope of Mauna Loa volcano on Hawai‘i (Hu et al. 2001, p. 235), one on a sheer cliff in remote Pōhakuao Valley on the Nā Pali coast of Kaua‘i (Wood et al. 2003, p. 8), and one in a small cave on Lehua Islet (VanderWerf et al. 2007, p. 47), which is located 0.6 miles (mi) (0.97 kilometers [km]) north of Ni‘ihau. All inactive nests were located in small caves or crevices and were confirmed by skeletal remains found in the nest. Data suggest that band-rumped storm-petrels prefer deeper crevices, compared to those available within 328 ft (100 m) of nest sites, as they may provide protection from invasive predators (Antaky et al. 2019, p. 4). No other nests have been found to date (Slotterback 2002a). Calling activity for band-rumped storm-petrels peaks from 60 to 120 minutes after sunset, as recorded by song meters on Lāna‘i (Raine et al. 2020a, p. 94).

Band-rumped storm-petrels are long-lived (15 to 20 years) and likely do not breed until at least the third year (Harrison et al. 1990, p. 148). In Hawai‘i, band-rumped storm-petrels breed once

per year, where a single egg is laid (Harrison et al. 1990, p. 140). When not at nesting sites, adults spend their time foraging on the open ocean for small fish, squid, and crustaceans. They are small, and therefore difficult to identify from similarly sized petrels. They differ from the closely related Leach's storm-petrel (*Hydrobates [Oceanodroma] leucorhous*) by flight style, which is less erratic in band-rumped storm-petrels, as well as tail structure and white band pattern (KESRP 2020). Band-rumped storm-petrels have been observed feeding during the day, but it is likely that they also feed at night (Harris 1969, p. 105). Little is known about the phenology of band-rumped storm-petrels in Hawai'i. However, a review of available literature performed by Wood et al. (2003, p. 18) on birds from Kaua'i indicates that the nesting cycle can last as long as 184 days from the arrival of adults to fledging of chicks. The study postulates that it is approximately 39 days from arrival to copulation, 33 days from copulation to egg laying, 42 days from egg laying to hatching, and 70 days from hatching to fledging (Wood et al. 2003, p. 18). This would mean that the arrival time for band-rumped storm-petrels in Hawai'i would be mid-May, with egg laying in mid-June, incubation until early August, and fledging in October (Raine et al. 2017, p. 78). However, birds may arrive earlier in the year and go through a pre-laying period of reproduction where they head out to sea after prospecting for burrows or attempting to breed, as seen with other Hawaiian Procellariids (Martinez-Gomez and Jacobsen 2004, p. 36).

The at-sea distribution of band-rumped storm-petrels in the Pacific Ocean is largely unknown, but birds have been seen 600 m (966 km) north of Hawai'i, 1,000 m (1,609 km) south of Hawai'i, and between Japan and Hawai'i. The Pacific populations of band-rumped storm-petrels are not known to range near the waters of the U.S. West Coast (Howell et al. 2010, p. 198). Band-rumped storm-petrels in the Atlantic are known to travel immense distances (Howell et al. 2010, p. 198), so it is possible that any of the Pacific records could include the Hawai'i DPS of band-rumped storm-petrels (KESRP 2020). Flock feeding is typical of this species, as is gregarious feeding. They've also been known to follow ships, and scavenge from these vessels (Bretagnolle 1993, pp. 141, 159-160).

Band-rumped storm-petrels throughout their global range show considerable geographic variation in several morphological characteristics, including bill and wing morphology, as well as rump coloration. One study demonstrated that birds breeding in warm surface waters tend to have longer bills and wings, and less white on the rump compared to those breeding in cooler waters (Howell et al. 2010, p. 202). Similarly, the overall color of the bird varies by climate. Dark colored birds are found to live in low latitudes and warm climates, while lighter colored birds were at high latitudes with cooler climates (Bretagnolle 1993, p. 147). Compared to individuals breeding in other parts of the species' range, birds breeding in Hawai'i are darker in color. However, Hawai'i DPS band-rumped storm-petrels can vary in their coloration depending on molting stage and time of year. Figure 2 (from Pyle et al. 2016) shows variation in both the coloration of the upper-wing ulnar bar, as well as the forking of the tail (in M1). The tail forking is likely a result of longer and narrower outer rectrices prior to molting. Hawaii band-rumped storm-petrels molt in fall through spring (Pyle et al. 2016, pp. 59, 72).



Figure 2. An image from Pyle et al. 2016 shows three Hawai'i band-rumped storm-petrel individuals with varying coloration as a result of feather age. M1 shows one-year old bird in second prebasic molt with a forked tail as a result of longer and narrower outer rectrices. M2 shows an adult with an upper-wing ulnar bar. M3 shows an adult with fresh feathers and almost no apparent ulnar bar.

Because of the small size of band-rumped storm-petrels, they are susceptible to predation from larger fish, such as sharks, while feeding out at sea (Garcia-Barcelona et al. 2019, p. 155). The dark plumage coloration of band-rumped storm-petrels likely acts as a cryptic color against the sea, reducing the likelihood of predation. Additionally, the dark coloration also provides protection against ultraviolet radiation (Bretagnolle 1993, p. 159).

Band-rumped storm-petrels, like several other seabirds in the order procellariiformes, show a strong attraction to light sources, including artificial lights (Raine et al. 2017, p. 75). Fallout is a term used to describe the grounding of seabirds due to the disorientation or collision, often caused by exposure to anthropogenic sources such as artificial lights, structures, or utility wires. Low levels of fallout have been recorded on Kaua'i since 1978, where rehabilitation of band-rumped storm-petrels is performed by the Save our Shearwaters (SOS) Program (Telfer et al. 1987, p. 480). Because of their large range, fallout can occur anywhere where birds may interact with artificial lights. Fallout has been reported from O'ahu, Kaua'i, and Hawai'i (USFWS 2020, unpublished data).

Individual Needs

Band-rumped storm-petrels spend more than half of their lives at sea, and only require land for breeding (Smith et al. 2007, p. 755). The current known breeding range of this species in the Hawaiian Islands is Hawai'i, Lāna'i, Kaua'i, and Lehua (USFWS 2015, p. 58822). Breeding is also suspected on Maui based on ground calling observations, but no known colonies exist. When breeding on land, band-rumped storm-petrels utilize dry cliff (dry grasslands and shrublands), wet cliff (wet forest), coastal cliff (coastal), and barren lava field habitat types (USFWS 2015, p. 58825; Clark et al. 2020, p. 6; Kim et al. 2020, p. 4; Pe'a et al. 2020, p. 4).

Band-rumped storm-petrels are ground nesting seabirds, which predominantly nest in cliffs or rocky lava fields (Raine et al. 2017, p. 79, Raine et al. 2020a, p. 94, Galase 2019, p. 27). The breeding habitats used by band-rumped storm-petrels on Kaua'i are among the best described. A

study by Wood et al. (2003) characterized the floral communities at suspected breeding sites. Each habitat type utilized for breeding contains different plant populations, depending on location and altitude. The dry cliff slopes of Pōhakuao on the Nā Pali coast lies just to the northeast of Kalalau and Hanakoa valleys. The birds likely nest on forested, towering basalt cliffs extending from sea level to 1,000 ft (305 m). The mesic cliffs in these areas are dominated by the shrub *Chamaesyce celastroides* var. *hanapepensis* (‘akoko), and two native grasses, *Eragrostis variabilis* (kawelu) and *Panicum lineale* (panic grass). Nu‘ololo ‘Āina is a mixed dry to mesic cliff community with towering basalt walls, that is located closer to the valley interior. The most abundant plants in the area were kawelu, *Lipochaeta connata* var. *acris* (nehe), *Bidens sandwicensis* (ko‘oko‘olau), *Artemisia australis* (‘ahinahina), *Nototrichium sandwicense* (kulu‘i), and *Sida fallax* (‘ilima). The Nu‘ololo Kai dry coastal cliffs are composed of native plant species such as nehe, ‘ahinahina, kulu‘i, *Myoporum sandwicensis* (naio), ko‘oko‘olau, *Panicum torridum* (panic grass), *Capparis sandwichiana* (maiapilo), and *Hedyotis st.-johnii* (kadua st.-johnii). The Waimea Canyon site is a dry forest habitat represented by the plants *Sapindus oahuensis* (kaulu), *Erythrina sandwicensis* (wiliwili), *Metrosideros polymorpha* (‘ōhi‘a), *Diospyros sandwicensis* (lama), *Psydrax odorata* (alahe‘e), *Acacia koa* (koa), *Nesoluma polynesianum* (keahi), *Charpentiera obovata* (pāpala), *Rauvolfia sandwicensis* (hao), and *Peperomia blanda* var. *floribunda* (‘ala‘ala) (Wood et al. 2003, pp. 6, 11–17).

Elsewhere, species plant communities have not been completely described. Band-rumped storm-petrels utilize coastal cliffs on Lehua islet, which is covered by more than 60 species of grasses, shrubs, and herbs, the majority of which are nonnative (Wood and LeGrande 2006, p. 19). Breeding colonies on Lāna‘i are suspected in dry grassland and shrubland habitat in Maunalei Gulch (Raine et al. 2020a, p. 94). On the island of Hawai‘i, extremely rocky lava fields, infrequently scattered with small ‘ōhi‘a trees and *Vaccinium reticulatum* (‘ōhelo ‘ai), are indicative of the habitat along the Mauna Loa slopes where burrows have been found (Banko et al. 1991, p. 650; Galase 2020, in litt.).

In Hawai‘i the only active nests that have been confirmed are on the island of Hawai‘i at the Pōhakuloa Training Area (PTA) on the slope of Mauna Loa, at an elevation of 2,100–2,200 ft (671 m) (Galase 2019, pp. 25–28). Visual sightings of birds circling the area, combined with acoustic monitoring data, and detector dog searches were successful in locating the nests, which were found in pāhoehoe lava aged 5,000 to 11,000 years old. The PTA nests were located in lava tubes, in extremely rocky terrain, with just a small opening needed to access the inner cavities of the lava field (Galase 2020, in litt.). No guano or any other visual signs were present that would elude to a nest in the area. On Maui no nests have been detected, but calls near Haleakalā crater near high barren laval flows are suspected nesting sites, as well as cliff areas along the leeward side of East Maui (MNSRP 2020). A dead bird was reported at the Makamaka‘ole seabird colony on Maui in an artificial burrow, which is in dry cliff habitat (Bogardus 2020, pers. comm.).

On Kaua‘i, Lehua, and Lāna‘i the breeding colonies are all located on sheer cliffs or rock outcroppings that are nearly inaccessible. Breeding on Kaua‘i was confirmed by the capture and banding of adult band-rumped storm-petrels from June to September (2015), of which more than 94 percent were reported to have brood patches (Raine et al. 2017, pp. 76–77). Brood patches are areas of featherless skin on the underside of birds, only present during nesting, which provide heat transfer needed for incubation of eggs. Once eggs have hatched, the parents brood the chick

for approximately one week until it can thermoregulate (Harrison 1990, p. 140). Soon after, the brood patch begins to re-feather, as was evident in birds captured in September after eggs had hatched (Raine et al. 2017, p. 77).

It is unclear if Hawai'i DPS band-rumped storm-petrel burrows are excavated or if birds utilize existing crevices for nesting. In the Galapagos Islands 171 nest sites were examined for band-rumped storm-petrels. Of those examined, nearly half were in holes in cliffs, with the most of the rest among boulders, or in caves. A total of five holes were excavated by birds in the soil, demonstrating that they are capable of burrowing in the substrate. In the cliff nest sites, half were located under substantial overhangs (Harris 1969, p. 104). Many Procellariids exhibit strong philopatry, returning to the same natal colony from which they fledged, but it is unknown if the same burrow is utilized from year to year (Smith et al. 2007, p. 755). The time of the year in which most young are fed (typically spring-summer) corresponds to the maximum availability of prey (Harrison 1983, p. 63).

The diet for band-rumped storm-petrels consists primarily of fish and squid, which is collected while just above the surface of the water, while pattering with their feet during flight. Band-rumped storm-petrels are well adapted for catching and holding slippery prey, as evident by the large number of big, backward-pointing spines that are found in the mouth (Harris 1969, p. 105). They primarily feed during daylight hours, opportunistically on any prey that is of appropriate size and occurs at or just below the surface (Harris 1969, p. 105; Harrison 1983, p. 62). It is probable that band-rumped storm-petrels also feed at night. The closely related Tristram's storm-petrel (*Hydrobates [Oceanodroma] tristrami*), which shares a foraging range with band-rumped storm-petrels, can feed at night, as evident from examined stomach contents (Harrison et al. 1983, p. 63). Outside of Hawai'i, band-rumped storm-petrels are known to feed on crustaceans, oily carrion, and garbage, in addition to fish and squids (Harrison 1990, p. 138).

Population Needs

Resiliency of band-rumped storm-petrels is measured by the capacity for the population to survive stochastic events and ecological disruption. Population estimates for band-rumped storm-petrels are unknown, but a study estimated between 171–221 nesting pairs on Kaua'i in 2002 (Wood et al. 2003, p. 6). The foraging range of the Hawai'i DPS of band-rumped storm-petrel is unknown, but it is suspected to be limited to the Pacific Ocean basin. Its range and occurrence when out at sea is poorly understood, and when on land its cryptic nature and remote nesting locations make it a difficult species to study.

Worldwide, band-rumped storm-petrels have sympatric but temporally isolated (allochronic) populations. Populations of band-rumped storm-petrels in Hawai'i and Japan only breed during the hot season (Friesen et al. 2007, p. 18593; Raine et al. 2017, p. 77). Conversely, in the Berlengas, Azores, and the Canary Islands of the Atlantic Ocean, populations breed only during the cool season. We interpret hot season to equate to summer seasons which are hot and drier in Hawai'i, versus cool seasons that equate to winter months where rain is abundant in Hawai'i. On Kaua'i birds have been detected as early as May and as late as September (Raine et al. 2017, p. 76). Other populations breed twice a year, or show evidence of some level of reproduction throughout the year (Bolton et al. 2008, p. 725).

Genomic analysis of band-rumped storm-petrels revealed up to seven unique clusters, and phylogenetic construction showed that they represent seven monophyletic groups (Taylor et al. 2019, p. 8). They found that populations from different archipelagos are genetically distinct, and that allochronic populations in different regions evolved independently (ex. hot breeders versus cold breeders). They concluded that band-rumped storm-petrels encompass multiple cryptic species, with non-geographic isolating mechanisms that are potentially acting as barriers to gene flow. This has implications for conservation as it can overestimate population sizes and ranges (Taylor et al. 2019, entire). Band-rumped storm-petrel populations in Japan and Hawai‘i appear to be the most genetically similar, and have the lowest level of genetic differentiation compared to other populations (Taylor et al. 2019, p. 9). An analysis of other physiological metrics, such as vocalizations, should be investigated to understand if the Japan and Hawai‘i populations truly represent distinct species. The sample size for each site was also small (Hawai‘i n=6, Japan n=8), and a more robust analysis with a larger sample size may allow for higher resolution.

The remote cliff and lava field environments in which band-rumped storm-petrel pairs breed are needed for the continued existence of the species. There are a number of threats, discussed below, that threaten both the quality and quantity of breeding and foraging habitat for band-rumped storm-petrels and include invasive species, habitat loss, and climate change.

Species Needs

The needs of band-rumped storm-petrels are measured by the metrics of redundancy and representation. Here, we measure the redundancy of band-rumped storm-petrels by the number of breeding sites across the known range and habitats of the species, as well as the distribution and connectivity of those breeding sites (Table 1).

Representation is determined by assessing the ability for this species to adapt to changing environmental conditions over time, across the range of habitat types that it occupies.

Representation for the band-rumped storm-petrel is also measured by the level of environmental variation in nest sites across the Hawaiian archipelago, the known nesting range for the Hawai‘i DPS, and how well secured the genetic structure is throughout the populations.

Band-rumped storm-petrels spend half their lives at sea, so a large portion of the life history of this species remains undescribed. Other Procellariids exhibit strong philopatry, and return to the same natal colony from which they fledged (Smith et al. 2007, p. 755). Habitat is somewhat limited on Kaua‘i and Lana‘i where band-rumped storm-petrels nest in sheer cliff sites, which are nearly inaccessible and make study of their breeding behaviors difficult. The remote nature of these areas makes estimating the total population of the species challenging. However, using auditory surveys, visual observation, and grounded seabird data from the Save our Shearwaters (SOS) program, the Kaua‘i population was estimated in 2002 as 171–221 nesting pairs (Wood et al. 2003, p. 1). At Lehua Islet bird calls were heard over a period of three years, and the skull of a juvenile was found in a cave, indicating breeding likely occurs on the islet (VanderWerf et al. 2007, pp. 42, 47). On Lāna‘i, auditory surveys near the Maunalei Gulch indicated very high call rates, as recorded by song meters (Raine et al. 2020a, p. 94). On Maui, birds were detected in Haleakalā Crater in 1970 and 1883, and between 3–5 individuals were estimated in a pre-listing survey in 1992 (Wood et al. 2003, p. 2). While no breeding sites have been confirmed on Maui, it is suspected on the slopes of Haleakalā, as well as near the Kahikinui Forest Reserve on the

leeward side of East Maui (MNSRP 2020). A bird was found dead in an artificial seabird burrow at the Makamaka‘ole seabird site in West Maui in 2020 (Bogardus 2020, pers. comm.). The only site where an active nest has been confirmed is at PTA on the island of Hawai‘i, and calls have been recorded from several areas within PTA (Galase et al. 2016, p. 16; Galase 2019, p. 25). An analysis of song meter data revealed the presence of band-rumped storm-petrels at 9 different sites on the northern slopes of Mauna Loa, with calls peaking 110 to 170 minutes after sunset (DOFAW 2019, p. 18). An analysis of song meter data from the eastern slope of Mauna Loa in the Hawai‘i Volcanoes National Park (HAVO) revealed numerous band-rumped storm-petrel calls, indicative of in-burrow calling that indicates the high likelihood of breeding in the area (HAVO 2020, p. 15). Band-rumped storm-petrel calls have also been detected along the southwest rift of Mauna Loa at elevations up to 9,000 ft (2,957 m) at volcanic cones (Banko et al. 1991, p. 653).

Antaky et al. (2020, entire) examined the patterns of genetic variation in band-rumped storm-petrel samples collected from within the State of Hawai‘i. Genetic samples came from Kaua‘i, O‘ahu, Maui, and Hawai‘i and were from recent collections, as well as historical specimens stored at Bishop Museum. Nine samples were collected from various locations on Kaua‘i, two samples came from downed birds on O‘ahu, two birds came from samples collected on Maui, and 11 samples came from PTA on the island of Hawai‘i (total n=24). Antaky et al. (2020, p. 6) examined both nuclear and mitochondrial DNA and determined that the highest level of genetic differentiation in Hawai‘i DPS band-rumped storm-petrels was among island groups. The Maui and O‘ahu samples showed no genetic differentiation, and were combined as a single clade (total n=4). The Kaua‘i and Hawai‘i island clades are distinct from the Maui/O‘ahu clade, and there is no evidence of inbreeding. It is interesting to note that the O‘ahu and Maui birds do not appear to assign to the same breeding colony as Kaua‘i and Hawai‘i island birds, suggesting the existence of an additional clade of band-rumped storm-petrels in the Hawaiian Islands. They also found an excess of rare alleles, low rates of inbreeding, and high nucleotide diversity (Antaky et al. 2020, p. 10). This genetic differentiation is similar to that seen in the Hawaiian petrel (*Pterodroma sandwichensis*), which breeds in multiple populations across the Hawaiian Islands (Welch et al. 2012, entire). The Antaky et al. (2020, p. 12) study suggests that loss of genetic diversity is likely not occurring in band-rumped storm-petrels. However, this analysis is based upon 24 individuals, including museum collections and bycatch birds that washed up on O‘ahu that are of an undetermined origin. Additional studies with a more robust sample size are needed, including individuals from the recently discovered colony from Lāna‘i.

Table 1. Metrics for assessing resiliency, redundancy, and representation

Conservation Biology Principle	Metric (s)	Notes
Resiliency	Capacity to survive stochastic events, ecological disruption	Limited breeding sites, increasing threats and increase of stochastic events likely
Redundancy	Number of breeding sites across range	Breeding across three islands, population numbers unknown
Redundancy	Distribution and connectivity	No evidence of inbreeding, suggests some connectivity among individuals

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Representation	Environmental variation (nest sites)	Two known nest site types, in cliffs and in barren lava fields
Representation	Population structure	Molecular data suggest two distinct genetic clades in Hawai‘i based on small sample size

FACTORS INFLUENCING VIABILITY

For the Hawai‘i DPS of band-rumped storm-petrel to persist into the future, factors influencing its viability must be addressed. There are a number of threats that may influence the continued existence of the species including predation, climate change, invasive species and habitat modification, stochastic events, light attraction and fallout, collisions, wind farms, and inadequate regulatory mechanisms (Table 2; USFWS 2016b, p. 67824). These threats are discussed below, along with conservation measures designed to counteract the effects of these threats.

Threats

Breeding colony predation

Introduced predators, primarily barn owls (*Tyto alba*), rats (*Rattus* spp.), mongooses (*Herpestes javanicus*), and cats (*Felis catus*) are believed to be the most serious terrestrial threat facing band-rumped storm-petrels in Hawai‘i. Band-rumped storm-petrels lack effective predator defenses and have a lengthy incubation and fledgling period, making adults, young, and eggs highly vulnerable to predation by introduced vertebrates. Due to the number of terrestrial predators that can impact birds at all life stages, they have an effect at the population level.

Wood et al. (2003, p. 4) observed introduced barn owls flying along basalt cliff faces where band-rumped storm-petrels likely nest in Pōhakuao, Kaua‘i. The closely related Newell’s shearwater (*Puffinus auricularis newelli*) and Hawaiian petrel both nest in remote, high-elevation sites on Kaua‘i close to band-rumped storm-petrels and barn owls are known predators of both species. From 2011–2018 they were confirmed to have killed 21 endangered seabirds (Raine et al. 2019a, p. 34). An additional two barn owl depredations were recorded at a single monitoring site during the 2019 seabird monitoring season (Raine et al. 2020b, p. 3). The loss of adult seabirds is of particular concern, as survivors of breeding age represent a loss of future breeding potential, as well as a decline in the population rate. Barn owls likely predate upon band-rumped storm-petrels as well, and a lack of direct evidence has been attributed to their small size and cryptic nature. According to a study by Raine et al. (2019a, p. 35), barn owls are regularly attracted to the calls of band-rumped storm-petrels at mist-netting sites, indicating a high likelihood that predation of the species occurs. In 2013, in the Nualolo ‘Āina area of Kaua‘i, the remains of a band-rumped storm-petrel was found consistent with barn owl predation (Raine et al. 2017, p. 79). Barn owls predate upon birds in the chick and adult life stage.

Rats are among the greatest threats to band-rumped storm-petrels and other ground-nesting seabirds, and are able to predate upon the species any time that they are on land. The three rat species that have been documented seabird predators in Hawai‘i are black rats (*Rattus rattus*), Norway rats (*R. norvegicus*), and Polynesian rats (*R. exulans*). In Newell’s shearwater nesting

colonies, rats have been observed predating upon all life stages of the bird on a near constant basis, but have the largest impact on eggs and chicks. Active seabird monitoring occurs in the montane colonies in, and nearby to, Kauaʻi's Hono O Nā Pali (HONP) Natural Area Reserve (NAR). At one management site within the HONP NAR monitored by cameras, a total of 1,942 rat visits were recorded on camera during the 2019 season (March to November) (Raine et al. 2020c, p. 36). Band-rumped storm-petrel populations on Kauaʻi, Lehua, and Lānaʻi all nest on cliff habitats, where access to nests is difficult. However, it does not remove the risk of all mammalian predators. On Kauaʻi, while performing auditory surveys for band-rumped storm-petrels in the HONP NAR, Wood et al. (2003, p. 8) noted that two live rats were observed walking on tiny rock ledges along vertical cliffs. In the same study, a cave that was accessible to researchers contained the bones of a small bird (suspected to be a band-rumped storm-petrel) along with rat bones, indicating that the two likely interact.

Predation from cats is another serious threat to the continued existence of band-rumped storm-petrels. Feral cats that roam Newell's shearwater and Hawaiian petrel nesting sites near the HONP NAR have been directly responsible for a large number of confirmed predation events since monitoring efforts began. Cat trapping takes place at three seabird breeding colonies within the HONP NAR. During the 2018 calendar year, a total of 30 cats were removed from baited traps within the three sites (Pias 2019, p. 17). Satellite/GPS tracking collars have been deployed on released cats to study their movement and habitat use within the HONP area (Pias et al. 2017, p. 41). Preliminary results of the study indicated that cats travel over large distances within the NAR, in one case covering 20,035 acres (ac) (8,108 hectares [ha]) over the course of 41 days (Dutcher 2020, in litt.). At the PTA nesting areas on the island of Hawaiʻi, cat scat was found near a possible burrow location, which contained bones that were likely from band-rumped storm-petrels (Galase et al. 2016, p. 20). While there is no direct evidence of cats predating upon eggs, they do kill adults and chicks. Any eggs left unattended as a result of parental cat predation would indirectly fail as a result.

In addition to threats from introduced predators, there are several native species that also threaten the band-rumped storm-petrel. The endemic pueo (*Asio flammeus sandwichensis*) has been seen circling seabird colonies during daylight hours on Kauaʻi, in areas where band-rumped storm-petrels are likely nesting (Wood et al. 2003, p. 4). This native owl has not been observed predating upon other native seabird species, but due to the small size of band-rumped storm-petrels, it is possible that predation could occur. The Galapagos short-eared owl (*Asio flammeus galapagensis*), which is similar in size to the pueo, is a known predator of band-rumped storm-petrels on those islands, as indicated by remains discovered in owl pellets (Harris 1969, p. 102).

Oceanic predation

The feeding behavior of band-rumped storm-petrels at the ocean's surface puts adult and sub-adult birds at risk from predatory fish that may attack while they are feeding. When band-rumped storm-petrels were examined near the Galapagos Islands, 7 percent of them showed injury to their feet, presumably from predatory fish (Harris 1969, p. 106). Stomach contents of blue sharks (*Prionace glauca*) caught off a commercial longline boat off Cape Verde in the Central Atlantic ocean were examined, and band-rumped storm-petrel remains were found in the stomachs of two sharks, indicating predation by sharks does occur (Garcia-Barcelona et al. 2019, p. 155). Blue sharks are found in temperate and tropical oceans including in those surrounding Hawaiʻi, along

with at least 39 other shark species. This individual threat can cause direct mortality to birds, or may damage or injure birds and reduce reproductive fitness.

Climate change

Large scale anthropogenic impacts like climate change are expected to alter wind and sea currents, potentially affecting flight and foraging patterns of band-rumped storm-petrels. According to the Intergovernmental Panel on Climate Change (IPCC), human activities have caused a 1°C increase in temperature above pre-industrial levels, and if the current rate of warming remains constant, we could reach an increase of 1.5°C by the year 2030 (IPCC 2018, summary for policymakers, A1, p. 6). A global warming of 1.5°C is expected to shift the range of many marine species to higher latitudes, and reduce the productivity of fisheries and aquaculture (IPCC 2018, B.4.3, p. 11). Ocean warming from climate change is expected to increase the thermal stratification in the upper ocean, reducing the upwelling of nutrients and decreasing productivity (Fabry et al. 2008, p. 426). Squid, a primary food source for band-rumped storm-petrels and many other seabird species, are predicted to undergo shifts in their range and size as a result of warmer ocean temperatures. Individual squid will require more food per unit body size, require more oxygen due to faster metabolism, have a reduced capacity to cope without food, and reduced seawater pH could affect the ability for squid to uptake oxygen (Pecl & Jackson 2008, p. 382). This threat is expected to impact all life stages of the bird from chick to adult, at the population level.

Shifts in food availability may occur based on sea surface temperature (SST). One of the primary food sources of band-rumped storm-petrel is squid, a type of mollusk from the class cephalopoda. While there have been studies predicting that the number of cephalopods will increase in some systems with increasing SST, the likelihood of ecological mismatch with band-rumped storm-petrels remains a possibility, and population expansion is not applicable to all cephalopod species (van der Kooij et al. 2016, p. 2285; Sakurai et al. 2002, p. 229). Higher between-year variance will be observed in surface feeding birds, which are more constrained in the water column because they can only exploit prey near the surface. In a meta-analysis a steeper negative slope was observed in birds with smaller body size to avoid incurring fitness costs of thermoregulation at higher temperatures, as well as with surface feeding birds as they are predicted to be more sensitive to the timing at which lower trophic-level-prey are available, placing band-rumped storm-petrels at increased risk for climate-induced mismatch due to shifts in timing of their prey (Keogan et al. 2018, pp. 315–316). This lack of food availability is expected to affect all feeding birds across the population.

An increase in large scale storm events as a result of climate change is expected to increase the intensity and frequency of storm events, which could directly impact nesting sites and lead to rockfalls that could kill or injure birds at all life stages (NASEM 2016, p. 109).

Invasive species and habitat modification

Ground-nesting seabirds and their offspring are particularly vulnerable to threats while on their breeding grounds, as they are unable or unwilling to depart the burrow in the event of nest disturbance. Invasive ungulates, such as pigs (*Sus scrofa*), goats (*Capra hircus*), axis deer (*Axis axis*), mule deer (*Odocoileus hemionus*) and mouflon sheep (*Ovis musimon*), are a threat to band-rumped storm-petrels, as their activities lead to modification of the native habitat. These

introduced ungulates are a threat to native ecosystems and have drastically altered native plant populations, most of which lack defensive mechanisms to deter herbivory (Chynoweth et al. 2010, p. 42). Their herbivory and trampling results in erosion, which washes away nesting habitat and makes the area susceptible to rockfalls. Rockfalls can directly injure or crush adults, as well as eggs and chicks. Additionally, ungulates facilitate the spread of nonnative plants, and severely degrade the landscape (Chynoweth et al. 2010, p. 44).

The invasion of seabird nests by ants is also an emerging threat to band-rumped storm-petrel burrows in Hawai‘i. Yellow crazy ants (*Anoplolepis gracilipes*) were observed invading nests of wedge-tailed shearwaters (*Ardenna pacifica*), a burrowing seabird species in Hawai‘i (Plentovich et al. 2017, p. 77). The number of active burrows decreased following the invasion of ants, likely as nest sites were abandoned prior to egg laying. In the event that hatching did occur, chicks in areas invaded by the ants displayed developmental abnormalities (Plentovich et al. 2017, p. 77). Boieiro et al. (2018, p. 48) observed that invasive ants killed a Barolo shearwater in Cape Verde, a species of seabird that nests in the same area as band-rumped storm-petrels. Yellow crazy ants are an emerging threat in coastal lowland areas such as Lehua and some areas of Kaua‘i, but elevation could be a limiting factor that would prevent invasion of nests in montane areas. Yellow crazy ants are typically found in elevations below 3,937 ft (1,200 m) (Abbott 2005, p. 266).

While not known from observations of band-rumped storm-petrels, an potential threat is feral honeybees (*Apis mellifera*), which have been observed invading burrows of Hawaiian petrels and Newell’s shearwaters that nest in the same habitat. Feral bees are recorded regularly in Kaua‘i’s HONP NAR and have caused both the abandonment of seabird burrows, as well as fatalities of seabird chicks and adults as a result of stings (Raine et al. 2020b, p. 48). In 2019, for example, there was a visit by bees at a monitored Newell’s shearwater burrow at the Pīhea seabird monitoring site. Bees were observed entering a previously occupied burrow, which ultimately failed for unknown reasons (Raine et al. 2020c, p. 47). In 2020, a swarm of feral bees inhabited a Procellariid seabird burrow at the Upper Limahuli Preserve, making it unavailable for the season, and potentially endangering seabirds in surrounding burrows (Nagendra 2020, pers. comm.).

Stochastic events

Stochastic events such as hurricanes, drought, and landslides have the potential to negatively impact band-rumped storm-petrel breeding grounds. The size and intensity of large-scale storms are expected to increase in coming years, and recent data demonstrates category 4 and 5 hurricanes have increased at a rate of 25–30 percent per °C increase in global warming (Holland & Bruyere 2014, p. 625). Specifically, Hawai‘i is expected to see an increased probability of active hurricane seasons, particularly during those years which coincide with an El Niño event (Murakami et al. 2015, p. S118). Because of climate change, there is an increased frequency of extreme El Niño events, and a warming of sea surface temperatures (SST) in the eastern Pacific where most Hawai‘i bound hurricanes originate (Cai et al. 2014, p. 115).

An increase in El Niño dry seasons, and subsequent La Niña wet seasons, is expected to alter rainfall levels in Hawai‘i, potentially leading to periods of drought or flooding that could have an effect on vegetation and nesting seabirds. Already, the recorded rainfall in Hawai‘i during La Niña years has undergone abnormal variability dating back to the early 1980s, with lower than

normal levels of precipitation observed (O’Conner et al. 2015, p. 7814). The western Pacific warming pool has expanded to nearly double its previous size from 1980 to 2018 (Roxy et al. 2019, p. 648). Modeling data shows a correlation between increased SST in the western Pacific warming pool and negative rainfall anomalies in Hawai‘i (O’Conner et al. 2015, p. 7820). This is particularly pronounced on the southern and western sides of O‘ahu and Kaua‘i, which would receive most of their precipitation during this period. This could lead to the death of vegetation, which helps to stabilize cliff areas where band-rumped storm-petrels nest. Conversely, La Niña wet seasons can lead to increases in large-scale rain and flooding events and landslides which can directly affect nesting areas.

Variability in rainfall levels and increases in storm events could lead to landslides, which could directly impact band-rumped storm-petrel nesting sites, as well as access for seabird monitoring. After historic flooding on Kaua‘i in early 2018, a number of landslides were reported in the Upper Limahuli Preserve (ULP) destroying seabird burrows and reducing access to the site (Raine et al. 2019b, p. 16). ULP is a known montane breeding site for the Hawaiian Petrel and Newell’s shearwater, but no band-rumped storm-petrel burrows have yet been observed. The breeding habitats are similar, and likely have a similar susceptibility for landslides. Subsequent landslides at ULP in 2020 caused the destruction of a seabird burrow belonging to an endangered Procellariid (Raine et al. 2020d, p. 17). This site, as well as others in the area, continue to be at risk for landslides due to their steep terrain, making management of this area a challenge for biologists (Nagendra 2020, in litt.).

Light Attraction and fallout

Band-rumped storm-petrels are particularly vulnerable to the effects of artificial lights, which act as an attractant, causing disorientation, confusion, and eventual grounding. The effects of artificial lights lead to a condition known as fallout, where fledgling young and adults are grounded and unable to regain flight, making them vulnerable to depredation or dehydration (Telfer et al. 1987, p. 410; Ainley et al. 2001, p. 109; Banko et al. 1991, p. 651). Newell’s shearwaters account for 95 percent of annual seabird fallout on the Kaua‘i, but small numbers of Hawaiian petrels and band-rumped storm-petrels are also recovered (Telfer et al. 1987, p. 407). This is thought to be an underestimate of actual fallout numbers for band-rumped storm-petrels due to their small size, and propensity for hiding once they fall to the ground. Though uncommon, fallout of band-rumped storm-petrels on O‘ahu has also been recorded (USFWS 2020, unpublished data).

Since 1979, a total of 40 band-rumped storm-petrels have fallen out and been processed by the SOS program on Kaua‘i, with an annual high of three birds in 2015 (Anderson 2015, pp. 4–13). The majority of these birds landed on various cruise ships transiting off the coast of Kaua‘i. The ships subsequently docked at Nāwiliwili Harbor, Kaua‘i and submitted injured birds to SOS for care (Anderson 2015, pp. 4–13).

A number of factors can influence the likelihood of fallout due to light attraction beyond just the presence of bright lights. These include factors such as moon phase, location of burrow in relation to human populations and the coastline, topography, cloud cover, bulb color and intensity, and light height (Troy et al. 2003, p. 226). Periods of diminished moonlight, such as

seen during a new moon phase, increases the likelihood that fallout will occur in Procellariid seabird species that nest on Kauaʻi (Troy et al. 2003, p. 232).

Collisions

When band-rumped storm-petrels were listed as endangered in 2016, collisions with structures was listed as a threat (USFWS 2016b, p. 67811). When birds become disoriented or blinded as a result of light attraction, they fly into unforeseen objects such as buildings or other structures (Telfer et al. 1987, p. 410). In addition to these light-caused instances, other stationary objects such as communications towers, poles, and power lines may pose a risk to transiting birds that might not see the objects on moonless nights. While not observed for band-rumped storm-petrels, Newell's shearwaters and Hawaiian petrels do interact with power lines. Dead seabirds for these federally listed species have been observed or seabird power line collisions have been detected at all power line regions and wire constructions on Kauaʻi, as reported by the Underline Monitoring Program (UMP) (Travers et al. 2020, p. 20). The UMP program revealed that 27 percent of the observed seabird power line collisions resulted in immediate and negative post-collision outcomes, including death and loss of flight. Approximately 70 percent of seabirds were able to maintain or regain flight following collision, but it is unknown if any deleterious effects may develop as a result of collision (Travers et al. 2020, p. 9).

Wind Farms

There is a lack of sound science that assess the effects of wind farms on seabirds (Green et al. 2016, p. 1,635). Band-rumped storm-petrels have lower wing loading (due to their small size) and can increase their air speed more proportionately than birds with higher wing loading, which may contribute to their interactions with wind farms (Spear and Ainley 1997, p. 241). Wind farms are a new threat to band-rumped storm-petrels, after the first death of a Hawaiʻi DPS bird was recorded in June of 2020 at Auwahi Wind on Maui (Salbosa 2020, in litt.). Prior to the incident, band-rumped storm-petrels had been excluded from incidental take permits issued to wind farm applicants, because they had not been previously recorded from the project areas and because of the overall rarity of the species in Hawaiʻi (USFWS 2019b, p. 53).

Inadequate Regulatory Mechanisms

Inadequate Habitat Protection: Nonnative feral ungulates pose a threat to band-rumped storm-petrels through destruction and degradation of the species' habitat and herbivory but regulatory mechanisms are inadequate to address this threat (USFWS 2015, entire). The State of Hawaiʻi provides game mammal (feral pigs and goats, deer, and mouflon sheep) hunting opportunities across the state (HDLNR 2015, pp. 19–21 and 66–77). However, the State's management objectives for game animals range from maximizing public hunting opportunities (e.g., "sustained yield") in some areas to removal by State staff, or their designees, in other areas (HDLNR 2015, entire).

Introduction of Nonnative Plants and Insects: Currently, four agencies are responsible for inspection of goods arriving in Hawaiʻi (USFWS 2015, entire). The Hawaiʻi Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawaiʻi, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations

(USFWS 2015, entire). The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest risk assessments among other activities. (HDOA 2009, p. 1). The Service inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq.*), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. The State of Hawai‘i allows the importation of most plant taxa, with limited exceptions (USFWS 2015, entire). It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities. Many invasive weeds established on Hawai‘i have currently limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2015, entire). Additionally, mongoose are not yet established on Kaua‘i or Lāna‘i and their introduction would lead to the decline of a number of avian species, including band-rumped storm-petrels (Duffy et al. 2015, p. 559).

Conservation Actions

In an effort to establish additional breeding colonies of band-rumped storm-petrels in Hawai‘i, social attraction sites are being established to attract birds to an area where they will be protected with predator control. Sites are fenced to exclude ungulates, and rat and cat trapping reduces or eliminates predation. One such social attraction site is currently in the works along the HONP coastline on Kaua‘i, and should be operational by the 2021 breeding season (Raine 2019, in litt.). The Makamaka‘ole seabird site on west Maui is a predator-proof fenced area that keeps out rodents, feral cats, and mongoose. This area has at least 100 artificial burrow boxes established for Hawaiian petrels and Newell’s shearwaters as part of the Kaheawa wind facility mitigation plan. In 2020, one band-rumped storm-petrel was found dead in a burrow, indicating that the social attraction site may also recruit band-rumped storm-petrels to the area (Bogardus 2020, pers. comm.).

Other management efforts that may benefit band-rumped storm-petrels, such as cat trapping, rat trapping, barn owl removal, ungulate fencing and removal, and predator exclusion fencing are currently being implemented at sites across the State of Hawai‘i. Cat and rat trapping is taking place in the HONP NAR on Kaua‘i by both the State, as well as private entities, who are funding mitigation sites as part of the requirements in their habitat conservation plans (HCPs). A five-mile cat proof fence was recently completed on Mauna Loa within HAVO designed to avoid disturbing nesting birds throughout their breeding season (HAVO 2021). In 2009 and 2017, the State of Hawai‘i in conjunction with federal partners, attempted to eradicate rats from Lehua Islet by broadcast aerial application of rodenticide (Siers et al. 2018, p. 10). As of 2020, no rats have been caught on monitoring cameras, and the most recent eradication efforts are presumed to have been successful. Additionally, barn owl control measures have been implemented on Lehua and Kaua‘i, leading to a significant decline in the number of seabird depredations (Raine et al. 2019a, p. 36).

To reduce fallout risk for fledging seabirds, a number of businesses and residents on Kaua‘i have shielded lights, so that they do not face upward and attract seabirds (Telfer et al. 1987, p. 412). This effort has been successful in reducing the level of fallout in some locations. To reduce the risk of collision with structures, reflective diverters have been added to some powerlines on Kaua‘i, and the static wire (where most collisions occur) has been removed from several high-strike line segments (Travers et al. 2020, p. 46). There are also outreach efforts from the State and Federal agencies to the public urging residents and businesses to turn off lights during the seabird fledgling season to reduce fallout risk.

The SOS program was established in 1979 by the State of Hawai‘i Department of Land and Natural Resources (DLNR). To date, this program has processed more than 30,000 endangered or threatened seabird species, including 40 band-rumped storm-petrels, many of which are released back to the wild. Satellite tagging of recovered and released birds indicates that most rehabilitated birds do survive after release (Raine et al. 2020e, entire).

Regulatory Actions

Endangered Species Act: The Service in 2016 determined endangered status under the Endangered Species Act of 1973 (Act), as amended, for 49 plants and animals from the Hawaiian Islands including the Hawai‘i DPS of band-rumped storm-petrel (USFWS 2016b, entire). The primary purpose of the Act is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the Act. Conservation measures provided to species listed as endangered or threatened under the Act include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The Act encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The Act and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the Act prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to agents of the Service and State conservation agencies. The Service may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act, is prohibited. Band-rumped storm-petrels occur on both Federal and non-Federal lands.

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Table 2. Factors influencing viability of the band-rumped storm-petrel

Threats & Conservation Actions	Threat (y/n/unk) and Conservation Action (y/n/unk if yes, then what)	Lehua	Kaua‘i	Lāna‘i	Hawai‘i
	<i>Climate change</i>	y	y	y	y
	<i>Conservation Action Implemented?</i>	n	n	n	n
	<i>Invasive species and habitat modification</i>	y	y	y	y
	<i>Conservation Action</i>	n	y, ungulate fencing	y,	y, cat proof fence within HAVO
	<i>Predation</i>	y	y	y	y
	<i>Conservation Action</i>	y, barn owl control	y, predator trapping and removal, barn owl control	y, cat and rat control	y, limited predator control for rats and mongoose near PTA
	<i>Stochastic events</i>	y	y	y	y
	<i>Conservation Action</i>	n	n	n	n
	<i>Light attraction & fallout</i>	n	y	unk	y
	<i>Conservation Action</i>	n	Light shielding, outreach	n	Light pollution ordinance
	<i>Collisions</i>	n	y	y	y
	<i>Conservation Action</i>	n	Diverter on power lines	n	n
	<i>Wind farms</i>	n	n	n	y
	<i>Conservation Action</i>	n	n	n	n
	<i>Fisheries interactions</i>	y	y	y	y
	<i>Conservation Action</i>	n	n	n	n

CURRENT CONDITION

Historical Condition

Historic Trends

This species was once found on all main Hawaiian Islands (Harrison 1990, pp. 139–140). Band-rumped storm-petrels currently occupy very limited breeding habitats on vertical cliff faces, as well as in barren lava fields, on four islands. This is thought to be a remnant of the original nesting range, which likely extended upwards from sea level, based on occurrences of bones found in midden sites along the shoreline on O‘ahu (Olsen and James 1982, p. 30). During pre-contact times, the absence of mammalian predators would have allowed ground-nesting seabird populations to extend far beyond their current range, but the true extent of their presence is unknown. According to Athens et al. (1999, pp. 171–172), the seabird population on the lower ‘Ewa Plain was extremely rich, and consisted of a number of ground-nesting species, including band-rumped storm-petrels. The evidence for this species in the region comes from sinkhole deposits. Radiocarbon dating of bones from the area puts their origin between 1573–1066 B.C, which lay underneath cultural midden deposits. Band-rumped storm-petrels were almost certainly present following Polynesian arrival in the islands, as their bones have been found in cultural middens and were likely so abundant that they were sourced as food for early settlers.

Historically, band-rumped storm-petrels were likely present on all of the main Hawaiian Islands from the islands of Ni‘ihau to Hawai‘i (Fig. 3). Fossilized remains have been found on the islands of Kaua‘i, O‘ahu, Moloka‘i, and Kaho‘olawe. Bones were found in sea level middens on Kaua‘i (Wood et al. 2003, pp. 3–4). Olsen and James (1982, pp. 30, 33) describe band-rumped storm-petrel bones as very common when discovered in cultural midden sites in Barber’s Point on O‘ahu. Only a few bones were discovered at a single midden site on Moloka‘i, despite intensive screening for small birds. On Kaho‘olawe, two humeri were recovered from sand dunes in 1984, west of Honokanai‘a, and in 1992 small portion of a humerus bone was discovered in a small lava tube in the Ahupu Gulch. Since no current population information is present, and a large number of feral cats are present on the island, it is possible but unlikely that breeding populations persist on Kaho‘olawe (KIRC 2015, p. 19). No fossils or other prehistoric remains have been identified on the islands of Ni‘ihau, Lehua, Lāna‘i, Maui, or Hawai‘i.

Band-rumped storm-petrels were first observed flying in the Kaulakahi channel in 1893 by Palmer, near the island of Ni‘ihau. Specimens of band-rumped storm-petrels were collected on Ni‘ihau prior to 1900 by Francis Gay, but no description of the habitat is noted (Fisher 1951, p. 36). Ni‘ihau is a privately owned island, and there are no observed records since the initial collections. Recent evidence of birds on the island of Kaua‘i are noted from collections at the Bishop Museum from Makaweli and Waimea collected in 1893–94, and from Hanapēpē Valley in 1979 (Wood et al. 2003, p. 3). The presence of a colony was reported from HONP Kaua‘i in 2001 and songs detected on Lehua in 2002 (Wood et al. 2003, pp. 3, 17–18). Additional monitoring using song meters on Lehua have detected calls that are concentrated on southeastern slopes, and not detected on other areas of the islet (Raine et al. 2017, p. 79). Calls from band-rumped storm-petrels were detected on Maui at Haleakalā Crater in 1970, and again in 1983. Band-rumped storm-petrels were first detected on the island of Hawai‘i in 1949 when a dead juvenile was collected at the Kīlauea Military Camp and a subsequent collection of remains on Mauna Loa in 1968. A live fledgling was collected at the Kulani Correctional Facility in 1988

(Wood et al. 2003, p. 2). There are no historic records known for band-rumped storm-petrels from Lānaʻi, and they were first detected on that island in 2018 using song meters (Raine et al. 2020, p. 94).

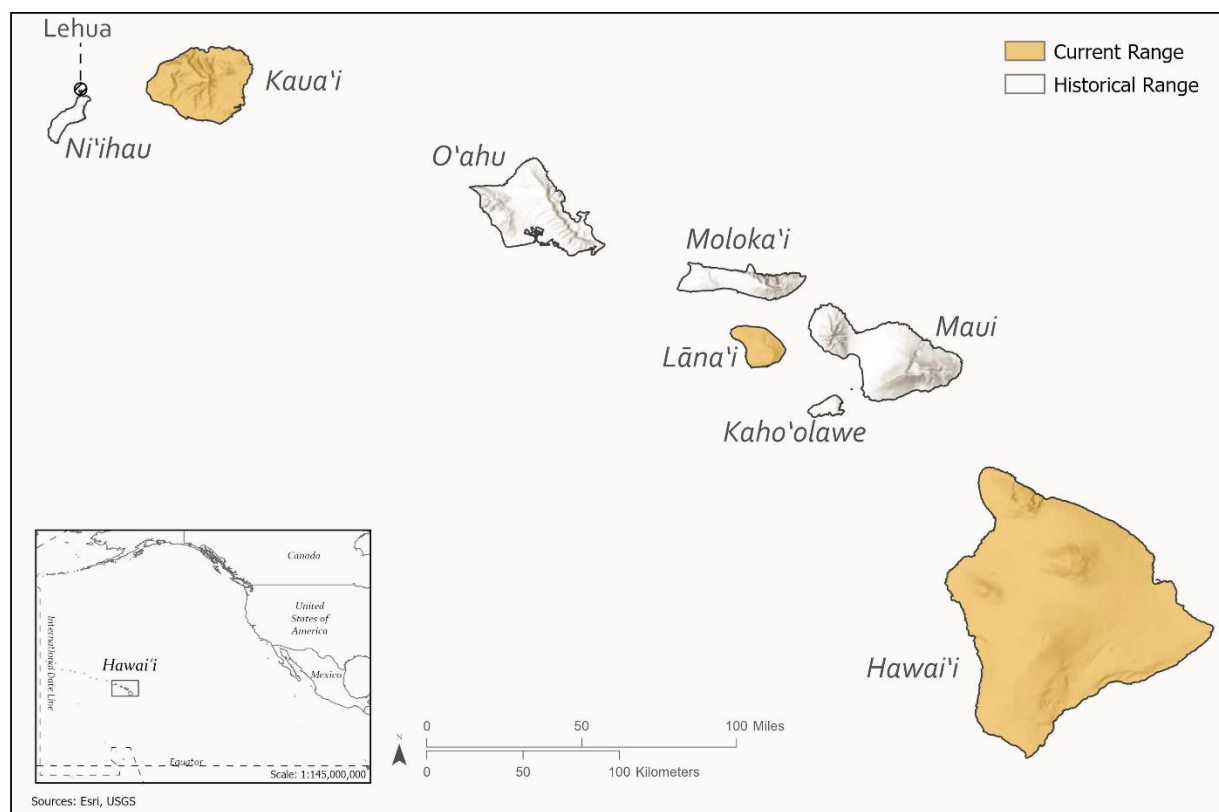


Figure 3. Current and historic range of the Hawaiʻi DPS of band-rumped storm-petrel (Source: USFWS 2020, Unpublished data)

Current Condition

Band-rumped storm-petrels are currently confirmed or likely breeding on Lehua Islet, Kauaʻi, Lānaʻi, and the island of Hawaiʻi (Figure 3). These are areas where there have been visual observations of the birds, ground calls recorded on song meters, or recent remains that indicate they are present and not just transiting through the area. The species may potentially breed on Maui, where inconclusive evidence exists.

On Lehua, the remains of a band-rumped storm-petrel chick were found on the islet, indicating that the species likely nests there even though no active nests were confirmed (VanderWerf et al. 2007, p. 39). The area where nesting is suspected on Lehua is mainly concentrated on the southeastern coastal steep slopes, with little vegetation (Raine et al. 2017, p. 79).

On Kauaʻi, Raine et al. (2017, pp. 74–79) used mist nets and acoustic monitoring to confirm the presence of band-rumped storm-petrels from June through October, which coincides with their breeding season. Birds were captured across multiple years, and for birds captured during the months from June to September (n=36), brood patches were recorded on 94.6 percent of birds.

They also recorded fledglings in the area, the majority of which were observed during October. On Kauaʻi, band-rumped storm-petrel breeding areas are found along the northwestern coast, with larger concentrations in the narrow valleys of the Na Pali coast, as well as the sheer walls of the Waimea Canyon in the southwest region. Small colonies were located on sparsely vegetated cliff faces in Lumahai and Wainiha valleys as well (Raine et al. 2017, p. 79). Wood et al. (2003, p. 6) located suspected band-rumped storm-petrel colonies in the Pōhakuao, Nuʻulolo ʻĀina, Nuʻulolo Kai, Kalalau, Awaʻawapuhi vista, Honopū, and Waimea valleys using visual observations, acoustic monitoring, and surveys performed by rappelling down the cliff face and searching for nests. Population estimates for band-rumped storm-petrels are unknown, but a study estimated between 171–221 nesting pairs on Kauaʻi in 2002 (Wood et al. 2003, p. 6).

Song meters have been used on Lānaʻi and band-rumped storm-petrels have been detected along Maunalei Gulch, with peak activity occurring 60 to 120 minutes after sunset (Raine et al. 2020a, p. 94). Due to the high volume of calls in the area, it is almost certain that band-rumped storm-petrels are breeding in the gulch.

On the island of Hawaiʻi, band-rumped storm-petrel breeding has been confirmed through the discovery of four active nests at PTA on the slopes of Mauna Loa (Galase 2019, p. 27). The nests were located in lava tubes on barren lava flows, with the aid of a detector dog, acoustic monitoring, night vision surveys, and remote camera surveillance (Galase 2019, p. 26). In addition, an analysis of song meter data revealed the presence of band-rumped storm-petrels at 9 different sites on the northern slopes of Mauna Loa, with calls peaking 110 to 170 minutes after sunset (DOFAW 2019, p. 18), indicating the presence of a wide distribution within this area. An analysis of song meter data from the eastern slopes of Mauna Loa in Hawaiʻi Volcanoes National Park (HAVO) revealed numerous band-rumped storm-petrel calls, indicative of in-burrow calling that indicates the high likelihood of breeding in the area (HAVO 2020, p. 15). Band-rumped storm-petrel calls have also been detected along the southwest rift of Mauna Loa at elevations up to 9,701 ft (2,957 m) at volcanic cones (Banko et al. 1991, p. 653).

On Maui auditory surveys have detected band-rumped storm-petrel calls at Haleakalā crater, as well as nearer to the ocean. Calls were first detected in 1970 within Haleakalā crater. Based on pre-listing surveys in 1992, three to five individuals were suspected from Maui and were detected over land during the presumed breeding season (Wood et al. 2003, p. 2). In addition, there have been reports of band-rumped storm-petrel calls being detected over the bogs of Haleakalā National Park, but to date no nesting colonies have been discovered in the area (Bailey 2009, pp. 2–3). In the West Maui mountains, two exclosures have been constructed at Makamakaʻole, designed to attract nesting seabirds to the site. In 2020, a dead band-rumped storm-petrel was discovered in one of the artificial burrows, suggesting that the species may be attracted to the site (Bogardus 2020, pers. comm.). Band-rumped storm-petrels are also suspected to nest in cliff sites in the Kahikinui Forest Reserve, and auditory surveys are underway to confirm their presence, prior to the construction of an ungulate-proof fence (Conservation Metrics 2020). Despite the presence of birds over the island, breeding sites of band-rumped storm-petrels have not been confirmed on Maui.

Although surveys have revealed the presence of band-rumped storm-petrels in several areas (Table 3), more auditory surveys are needed over a larger area to assess the true distribution of

the species across the Hawaiian Islands. No population numbers for the Hawai'i DPS of band-rumped storm-petrel are known, and more robust auditory surveys could aid in determining baseline levels, and recovery of the species.

Table 3. Current and suspected breeding sites of band-rumped storm-petrel.

Island	Habitat Type	Last Observation Date*	Extant? (Y/N/Unk)
Lehua	Cliff	2007	Y
Kaua‘i	Cliff	2020	Y
Lāna‘i	Cliff	2020	Y
Hawai‘i	Lava field	2019	Y

* If known

SPECIES VIABILITY SUMMARY

The viability of the Hawai‘i DPS of band-rumped storm-petrel is based on the species resiliency, redundancy, and representation. Based on the best available data for band-rumped storm-petrels, the overall viability for this species is determined to be low (Table 4).

Resiliency

The resiliency is determined to be low, based on the fact that there is low capacity for the population to survive stochastic events and a high number of threats that impact this species, many of which can lead to ecological disruption (Table 4). Known breeding colonies are confined to steep cliff faces and barren lava fields, and are vulnerable to stochastic events. The foraging range of the Hawai‘i DPS of band-rumped storm-petrels is unknown, but it is suspected to be limited to the Pacific Ocean basin. Its range and occurrence at sea is poorly understood, and when on land its cryptic nature and remote nesting locations make it a difficult species to study. Because the total population size is small, this species remains at a high level of risk due to the increasing threat of stochastic events in Hawai‘i, as well as a high number of threats which are likely to cause continued ecological disruption.

Redundancy

The redundancy of the Hawai‘i DPS of band-rumped storm-petrel is low (Table 4), based on the fact that there is one breeding population. Few breeding sites of band-rumped storm-petrels are known, and the distribution and connectivity among individuals in those sites is poorly known (Table 1). There is no total population estimate for band-rumped storm-petrels due to a lack of available data. Surveys on Kaua‘i estimated that as many as 221 birds were present in surveys performed in 2002 (Wood et al. 2003, p. 6). A total of four nests were located at PTA on the island of Hawai‘i, indicating the presence of at least eight birds in this area, with additional birds spread across other areas of Mauna Loa. No population estimates are available for Lehua or Lāna‘i. These estimated numbers are likely much lower than the actual population numbers, but the cryptic nature of this species makes accurate population estimates challenging. According to a genetics study by Antaky et al. (2020, p. 12) there is no evidence of inbreeding among Hawai‘i DPS band-rumped storm-petrel individuals analyzed and suggests some level of connectivity among subpopulations across the islands.

Representation

The representation of band-rumped storm-petrels is low. Representation is determined by assessing the ability for this species to adapt to changing environmental conditions over time, across the range of habitat types that it occupies, and how well secured the genetic structure is throughout the population. Representation for band-rumped storm-petrels is measured by the level of environmental variation in nest sites across the Hawaiian archipelago, the known nesting range for the Hawai'i DPS, and by the genetic structure measured within the population. Currently, band-rumped storm-petrels are known to nest in poorly vegetated vertical cliff sites on Lehua, Kaua'i, and Lana'i. They nest in barren lava fields on Mauna Loa on the island of Hawai'i. The availability of both habitat types is somewhat limited across the archipelago, and are subjected to a high number of threats. Historic data suggests that band-rumped storm-petrels are capable of nesting in other habitat types down to sea level. However, with the presence of invasive mammalian predators in the islands, an expansion of nesting sites outside of their current locations is unlikely without conservation interventions. An analysis of individuals collected from across the Hawai'i DPS range indicates that there is population structure associated with this species (Antaky et al. 2020, p. 12). There are currently two distinct clades present in the Hawaiian Islands, one for the Hawai'i and Kaua'i birds and another for downed birds collected from Maui and O'ahu. A more robust study with a larger sample size is needed to further elucidate genetic trends among islands.

Table 4. Viability of current condition of band-rumped storm-petrel.

Species Name	Overall Resiliency	Redundancy	Representation	Viability
Band-rumped storm-petrel	Low	Low	Low	Low

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